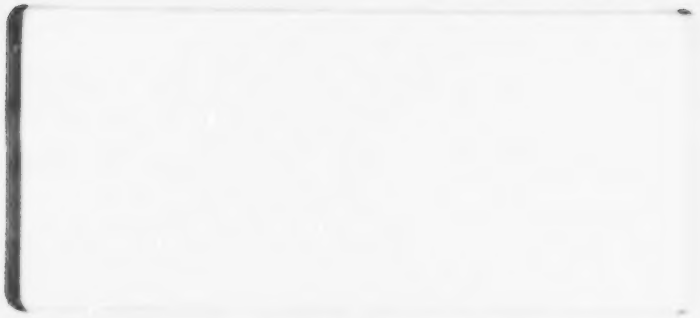

Manitoba
Environment
and Workplace
Safety and Health

MG-8159

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DATE: February 2, 1987

Source Testing for Particulate Emissions From the Pathological Incinerator at Morden District General Hospital, Morden, Manitoba, 1986.

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Environmental Control Services,
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ABSTRACT

During September 1986 six source emission tests were conducted on the incinerator at Morden District General Hospital. Particulate emissions from Tests 1 to 5 varied from 0.32 grams per dry standard* cubic metre (g/dscm) to 1.25 g/dscm when corrected to 12% CO_2. During those tests changes and adjustments were made to both the combustion control devices and loading procedures.

Test 6, which reflected those changes, indicated a particulate emission of 0.14 g/dscm when corrected to 12% CO_2. This was in compliance with Manitoba Regulation 334/74, Section 3(1).

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* temperature 20°C, pressure 760 mm Hg

INTRODUCTION

A new pathological incinerator was installed at Morden District General Hospital to completely destroy pathological and general hospital wastes, expired drugs and small pieces of sharp apparatus.

Previous surveys had indicated that similar refuse and/or pathological incinerators may not be in compliance with existing environmental legislation, especially if waste loading procedures, combustion air, gas burner settings and high temperature cut out limit are not all coordinated to produce the most efficient combustion possible for that particular set of circumstances.

After each test the data were analyzed to determine incinerator operating characteristics. Carbon dioxide (CO_2), Carbon monoxide (CO), Oxygen (O_2), water vapor, gas velocity and high limit (temp.) cut out were all correlated so as to enable the incinerator to be adjusted to completely destruct all loaded materials while minimizing stack particulate emissions.

A representative from the incinerator manufacturer was on location to load the incinerator in the recommended manner as well as to make adjustments during and after the testing.

PROCESS DESCRIPTION

A Plibrico Model CAB 100P multiple chamber incinerator was tested for particulate emissions. Figure 1 depicts the incinerator as installed in the boiler room of Morden District General Hospital. The design capacity was 100 cubic feet of Type I waste (normal rubbish) and Type IV waste (pathological) per cycle. The primary and after burner chambers were heated by natural gas burners with a total heat input capacity of 900,000 BTU/hr. The incineration process was automatically controlled by a programmable operation cycle timer, which determined the sequence and duration of firing in the two chambers. The operational cycle was modified during the testing program to attain optimum combustion conditions. See Table 1 for a reference example of the cycle during the testing. Drying, ignition and partial combustion of the waste occurred in the pathological and primary chambers. Air intake to the primary chamber was reduced to control the combustion rate and temperature. This prevented turbulent high velocity gases from developing which could have transported ash particles into the after burner chamber. Final combustion of gasified and partially combusted volatile components occurred in the after burner chamber, where air was supplied in excess of stoichiometric requirements to ensure complete combustion.

Various combustion products exit through a 7.6 m (25.0 ft.) steel stack. A ceramic liner was installed as an insulator. The stack had a continuous inside diameter of 45.7 cm (18 in.). Overall

stack height above grade was 9.9 m (32.3 ft.) and exceeded the height of the boiler room by 4.3 m (14.0 ft.). A 0.7 m (2.3 ft.) tall stainless steel mesh basket was located on top of the stack as a spark arrestor.

When the incinerator had cooled, ash was removed from the primary chamber.

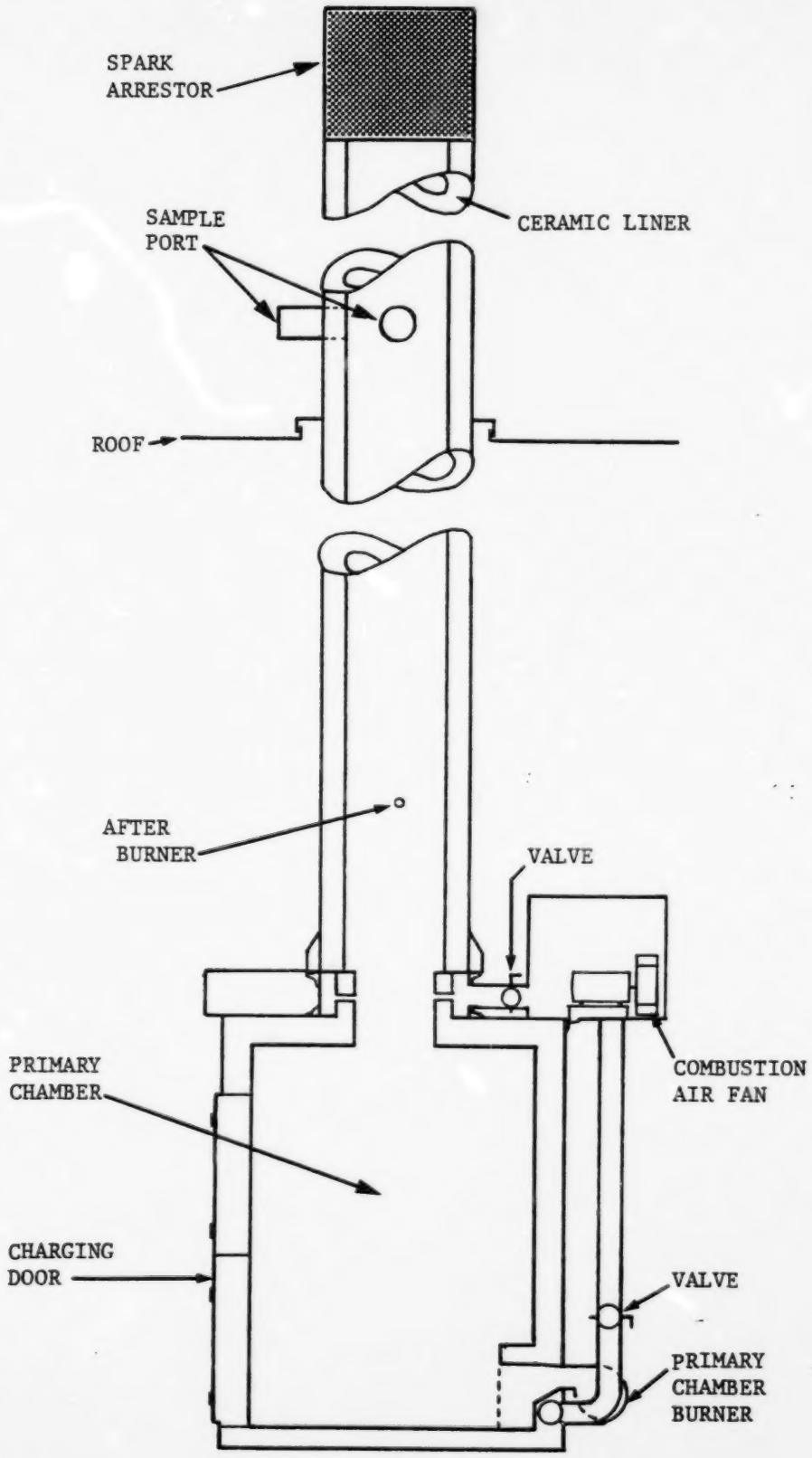


FIGURE 1. PLIBRICO CAB 100P INCINERATOR AS INSTALLED AT MORDEN DISTRICT GENERAL HOSPITAL

TABLE 1: INCINERATOR OPERATIONAL CYCLE

ITEM	TIME (Hours:Minutes)
CYCLE INITIATED	0:00*
AFTER BURNER ON	0:01
COMBUSTION BLOWER ON	0:51
PRIMARY BURNER ON	0:52
PRIMARY BURNER OFF	2:52
AFTER BURNER OFF	4:31
COMBUSTION BLOWER OFF	8:21

* Start time is expressed as 0:00 hrs. for comparison purposes only

PROCESS SCHEDULE

Charging material for the 1986 emission tests included 1) general hospital wastes (packaged in green garbage bags), 2) pathological wastes (packaged in red garbage bags), 3) special wastes such as sharp surgical items, glass ampules and out of date drugs (packaged in sealed cardboard boxes) and 4) empty cardboard boxes. The charging schedule can be found in Table 2.

TABLE 2: INCINERATOR CHARGING SCHEDULE

TEST NUMBER & DATE	CHARGE	COMMENTS
1 - September 8, 1986	70 cu. ft.	
2 - September 10, 1986	100 cu. ft.	(wet waste placed on top of dry waste)
3 - September 11, 1986	100 cu. ft.	
4 - September 16, 1986	100 cu. ft.	(empty cardboard boxes crushed and placed on incinerator floor)
5 - September 17, 1986	100 cu. ft.	
6 - September 22, 1986	100 cu. ft.	(empty cardboard boxes crushed and placed on incinerator floor)

TEST PROCEDURES

Sampling for Tests 1 to 5 was conducted through two ports located at right angles to each other (southwest and northwest) 3.7 m (12.0 ft.) above the after burner nozzle and 3.2 m (10.4 ft.) below the top of the stack. This corresponds to 8.0 and 6.9 duct diameters respectively of unrestricted flow before and after the sampling location. Four points were sampled along each traverse according to Environmental Protection Service (EPS) Method A specifications. The sample points, located 3.0, 11.4, 34.3 and 42.7 cm (1.2, 4.5, 13.5 and 16.8 in.) respectively from the inner stack wall are depicted on a cross section of the stack in Figure 2. Sampling intervals were five minutes per point.

Sampling for Test 6 was conducted through the southwest port only. By the conclusion of Test 5 noticeable nozzle disintegration had occurred. For Test 6 a new nozzle was used but sampling was limited to one port so as to eliminate the effects of heating, cooling and then reheating the nozzle during the move to the second port. Four points were sampled for 10 minutes each (in 5 minute intervals). The sample points, at the same locations as above, are depicted on a cross section of the stack in Figure 3.

Source emission testing was conducted according to EPS Method E, with one exception. To eliminate metal fatigue caused by the high stack gas temperature, the probe was water cooled rather than electrically heated. Figure 4 illustrates the particulate stack sampling train. The sample was drawn into a 12.57 mm (0.495 in.)

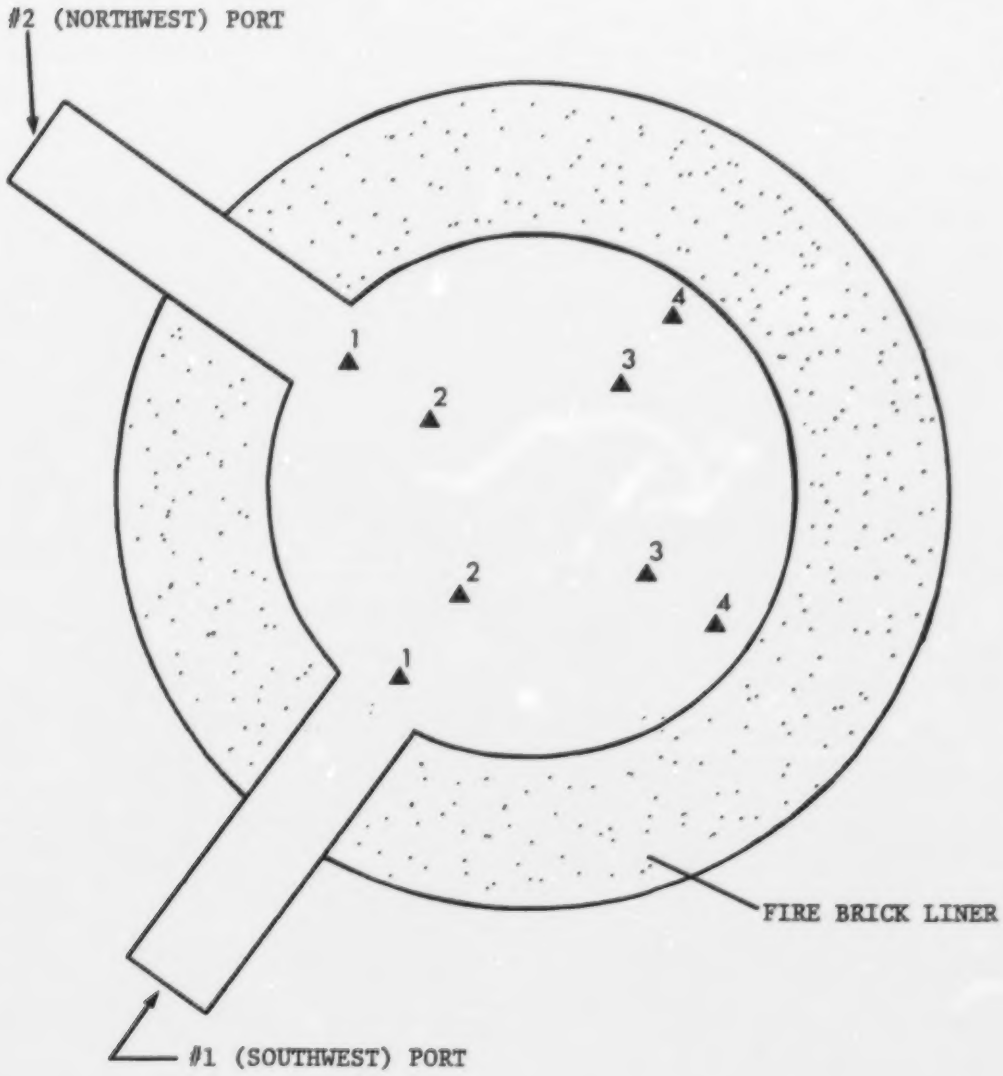
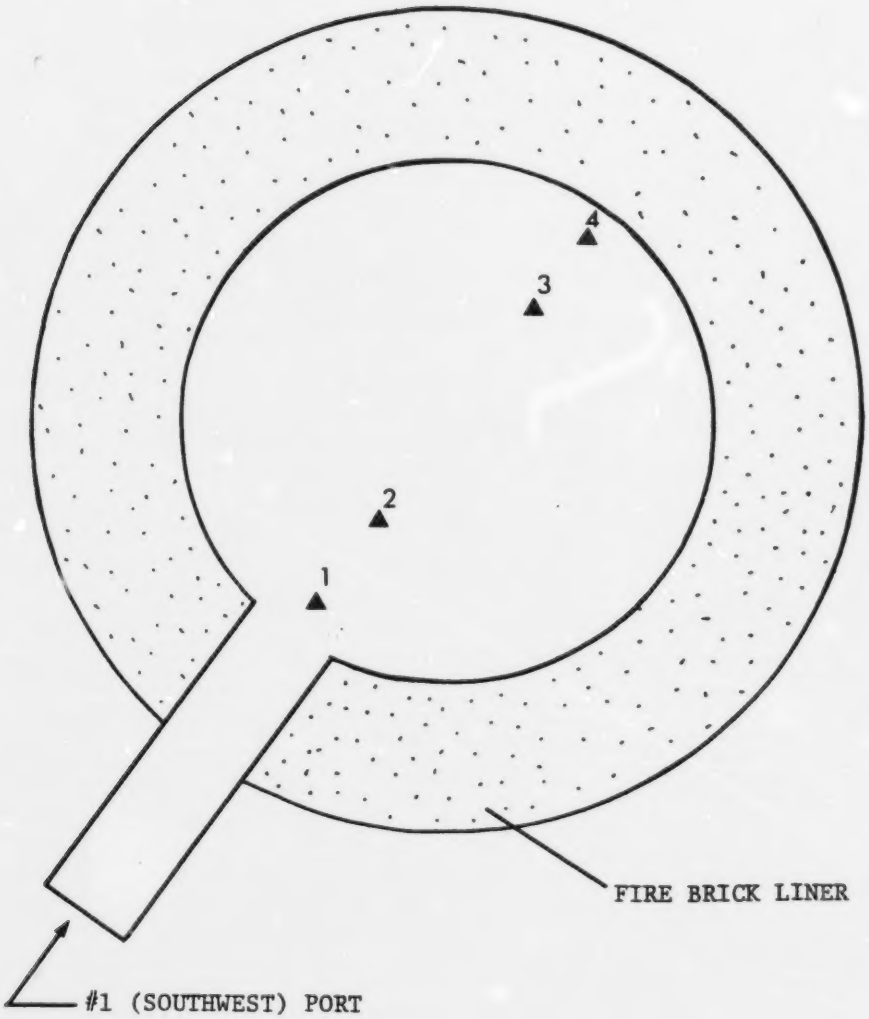


FIGURE 2. STACK CROSS SECTION DEPICTING SAMPLE POINTS FOR TESTS 1 TO 5.



▲ = SAMPLE POINT LOCATION

FIGURE 3. STACK CROSS SECTION DEPICTING SAMPLE POINTS FOR TEST 6.

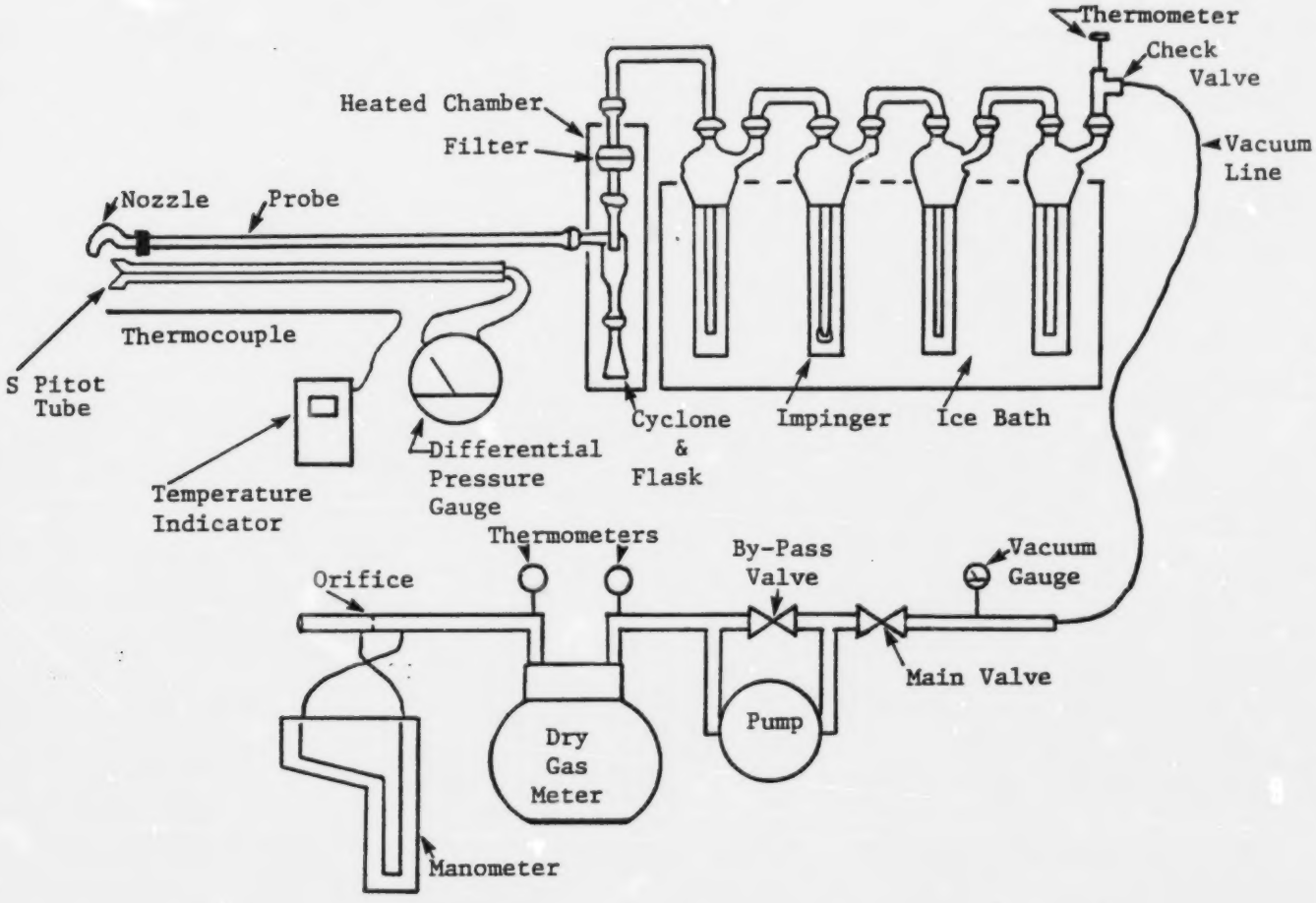


FIGURE 4. PARTICULATE STACK SAMPLING TRAIN.

nozzle, through a stainless steel probe and into a miniature cyclone which removed particulate matter of greater than 10μ diameter. The sample was then passed through a Whatman 934 AH glass microfiber filter (supported by a porous fritted glass disc) which removed particulates of 0.3μ diameter and greater. Both the cyclone and the filter were heated to prevent moisture from condensing on the glassware. The sample was then passed through four 500 ml Greenburg-Smith impingers connected in series in an ice bath. The first, third and fourth impingers had modified straight tips while the second was of the standard design. The first and second impingers contained 100 ml of deionized water. The third impinger was initially empty while the fourth contained 200 grams of indicating silica gel to remove any remaining moisture from the gas sample.

A Bendix Series 4500 Isokinetic Stack Sampler was used to extract the samples from the stack. Gas velocity in the stack was measured with an S type pitot tube and a Dwyer Magnehelic Differential Pressure Gauge (range 0 to 0.25" H_2O, minor division 0.005" H_2O). Dry gas meter and pitot tube calibration data sheets are located in Appendix A. A Nova Analytical Systems Model 370 Portable Flue Gas Analyzer (ranges: CO_2 0-20%, O_2 0-25%, CO 0-2000 PPM and 0-4%) was used to analyze the stack gas at one minute intervals during the testing. Stack temperature was measured by a K type thermocouple.

After sample recovery from the stack train, samples were submitted to the W. M. Ward Technical Services Laboratory for gravimetric analyses of particulates. Because the nozzle was not water cooled (and therefore subject to metal fatigue) the particulate matter extracted from it was not included in the sample submitted to the lab. As a further precaution the probe washings and filters were analyzed by atomic absorption spectroscopy for iron (Fe), chromium (Cr), nickel (Ni) and molybdenum (Mo) - the major components of the type 316 stainless steel nozzle and probe that could have contaminated the samples.

The sampling team consisted of Kevin Reeve, Art Schultz and Barry Cowan. Leonard Howells of Plibrico (Canada) Limited, the incinerator manufacturer, adjusted the natural gas flow rate, combustion air volume and high limit temperature (cut out) during the testing.

RESULTS

During the testing program the incinerator was controlled by a programmable operational cycle timer. Modifications and adjustments were made during and/or following Tests 1 through 5 in order to increase unit efficiency.

Important sampling parameters are summarized in Table 3. Source emission data are summarized in Table 4. Combustion analyses during the tests are depicted in Graphs 1 to 6. Refer to Appendices B, C and D respectively for velocity profiles, field data sheets and laboratory analytical reports.

The metals collected in the probe and filter samples (from nozzle disintegration) were subtracted from the particulate results before source emission data were calculated.

LEGEND FOR COMBUSTION ANALYSES GRAPHS

SYMBOL	PARAMETER-UNITS
⬢	O_2 in % by volume
▼	CO in PPM by volume
●	CO_2 in % by volume
•	Temperature in °F

TABLE 3: SUMMARY OF SAMPLING PARAMETERS

TEST NUMBER	1	2	3
SAMPLING DATE	Sept. 8/86	Sept. 10/86	Sept. 11/86
SAMPLING DURATION, min.	40	40	40
SAMPLE VOLUME AT METER CONDITIONS, m^3	0.5917	0.4680	0.3957
SAMPLE VOLUME AT STANDARD CONDITIONS, dscm*	0.5550	0.4458	0.3756
AVERAGE GAS METER TEMPERATURE, °C	32	29	30
ORIFICE PRESSURE DROP, mm H_2O	24.00	15.04	11.40
STACK STATIC PRESSURE, mm H_2O	-3.05	-3.94	-3.94
AVERAGE STACK GAS TEMPERATURE, °C	717	886	1033
AVERAGE STACK GAS VELOCITY, m/s	7.0	7.4	6.7
ISOKINETIC FACTOR, %	106.6	106.4	101.8

*Standard Conditions are 20°C and 760 mm Hg

TABLE 3: (CONTINUED)

TEST NUMBER	4	5	6
SAMPLING DATE	Sept. 16/86	Sept. 17/86	Sept. 22/86
SAMPLING DURATION, min.	40	40	40
SAMPLE VOLUME AT METER CONDITIONS, m^3	0.4176	0.4049	0.4667
SAMPLE VOLUME AT STANDARD CONDITIONS, dscm*	0.4000	0.3776	0.4385
AVERAGE GAS METER TEMPERATURE, °C	33	36	34
ORIFICE PRESSURE DROP, mm H_2O	12.3	11.6	14.22
STACK STATIC PRESSURE, mm H_2O	-3.94	-3.94	-3.94
AVERAGE STACK GAS TEMPERATURE, °C	1050	1070	1037
AVERAGE STACK GAS VELOCITY, m/s	6.9	6.9	7.3
ISOKINETIC FACTOR, %	104.3	106.6	109.1

*Standard Conditions are 20°C and 760 mm Hg

TABLE 4: SOURCE EMISSION SUMMARY

TEST NUMBER		1	2	3
STACK GAS COMPOSITION DRY BASIS,	CO_2, % BY VOLUME	7.5	12.0	12.6
	O_2, % BY VOLUME	11.2	6.0	4.9
	CO, ppm	653	-	205
STACK GAS MOISTURE, % BY VOLUME		13.7	15.7	14.8
Ms**, g/g-mole		28.05	28.25	28.40
AVERAGE STACK GAS VOLUMETRIC FLOW RATE, dscm/h		1029	829	731
CONCENTRATION OF PARTICULATE IN THE STACK GAS, g/dscm:	AT STACK CO_2	0.46	1.25	0.56
	AT 12% CO_2	0.73	1.25	0.53
EMISSION RATE OF PARTICULATE, kg/h		0.47	1.04	0.41

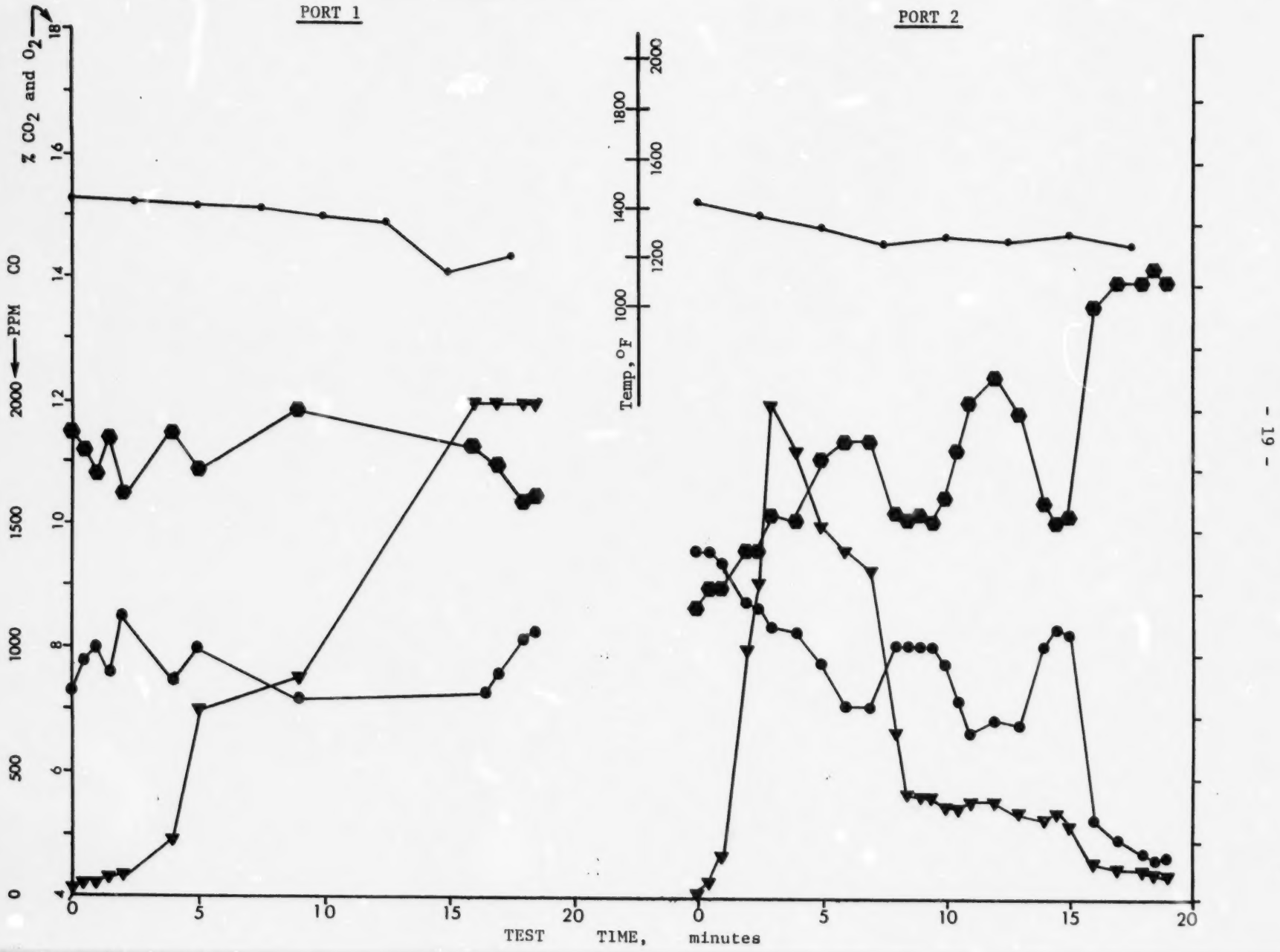
** Molecular Weight of the Stack Gas on a Wet Basis

TABLE 4: (CONTINUED)

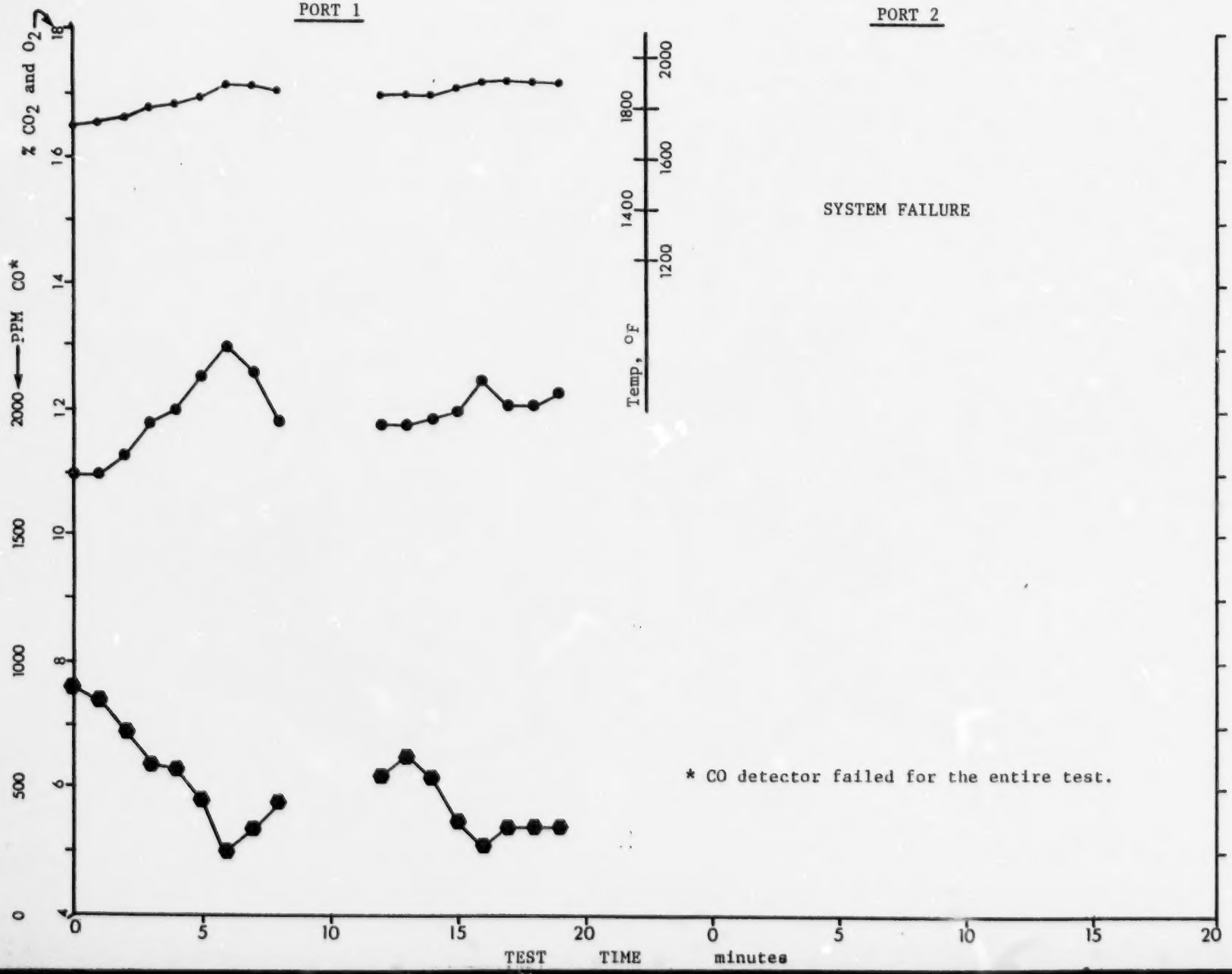
TEST NUMBER		4	5	6
STACK GAS COMPOSITION DRY BASIS,	CO_2, % BY VOLUME	12.7	13.1	13.6
	O_2, % BY VOLUME	6.0	4.5	4.4
	CO % BY VOLUME	65	66	54
STACK GAS MOISTURE, % BY VOLUME		15.2	18.9	14.5
Ms**, g/g-mole		28.36	27.96	28.56
AVERAGE STACK GAS VOLUMETRIC FLOW RATE, dscm/h		758	703	797
CONCENTRATION OF PARTICULATE IN THE STACK GAS, g/dscm:	AT STACK CO_2	0.34	0.88	0.16
	AT 12% CO_2	0.32	0.81	0.14
EMISSION RATE OF PARTICULATE, kg/h		0.26	0.62	0.12

** Molecular Weight of the Stack Gas on a Wet Basis

GRAPH 1. COMBUSTION ANALYSES DURING TEST 1.

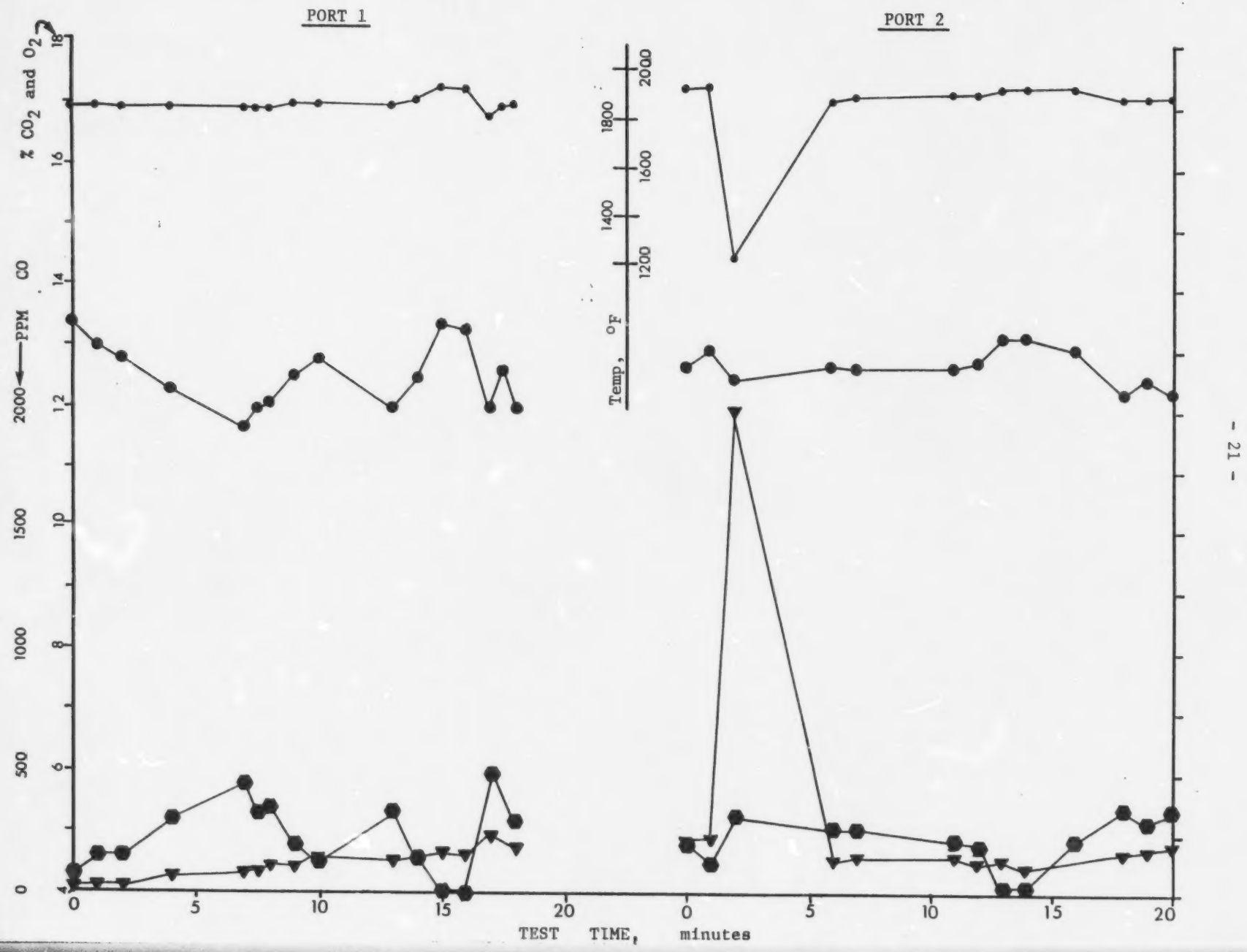


GRAPH 2. COMBUSTION ANALYSES DURING TEST 2.

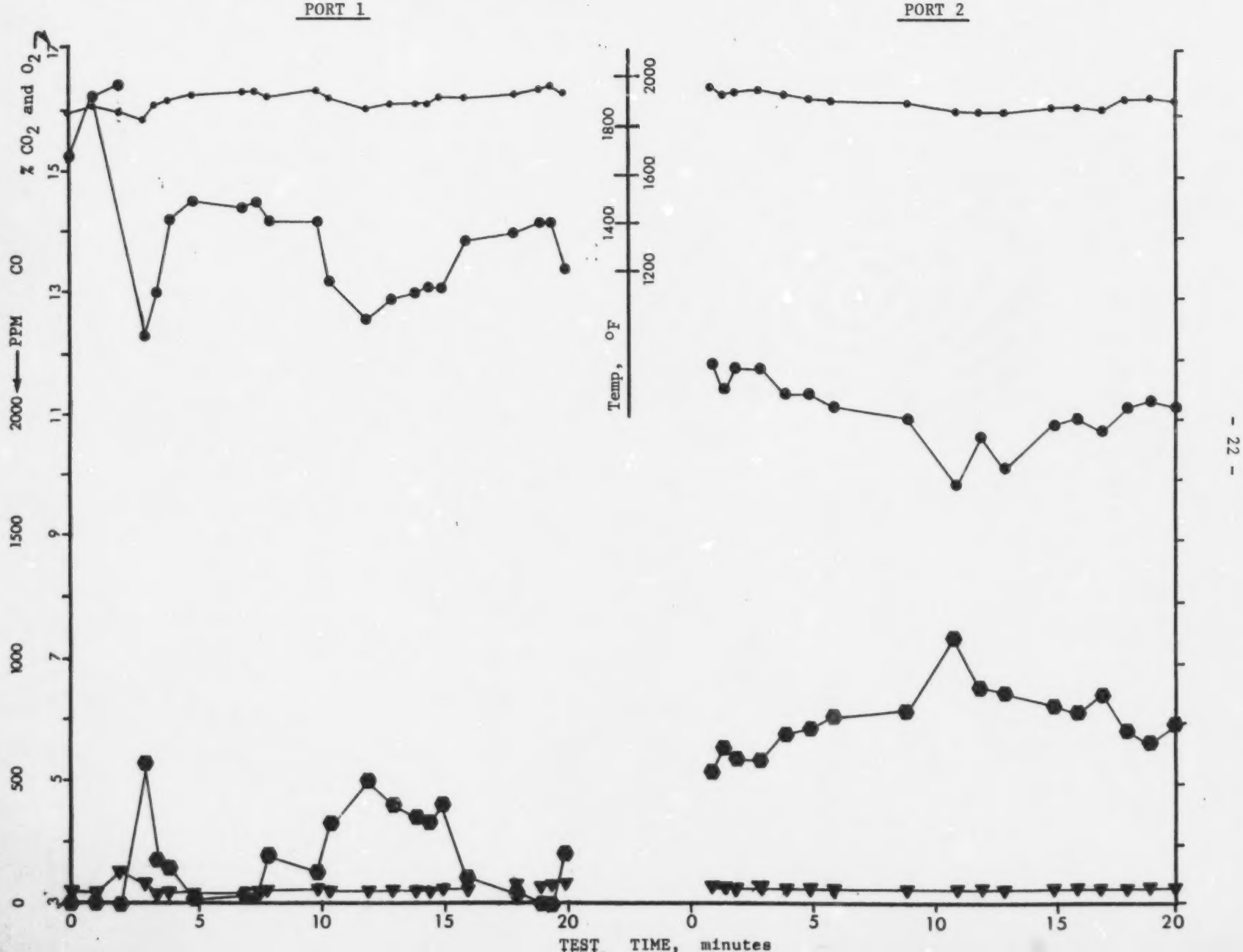


* CO detector failed for the entire test.

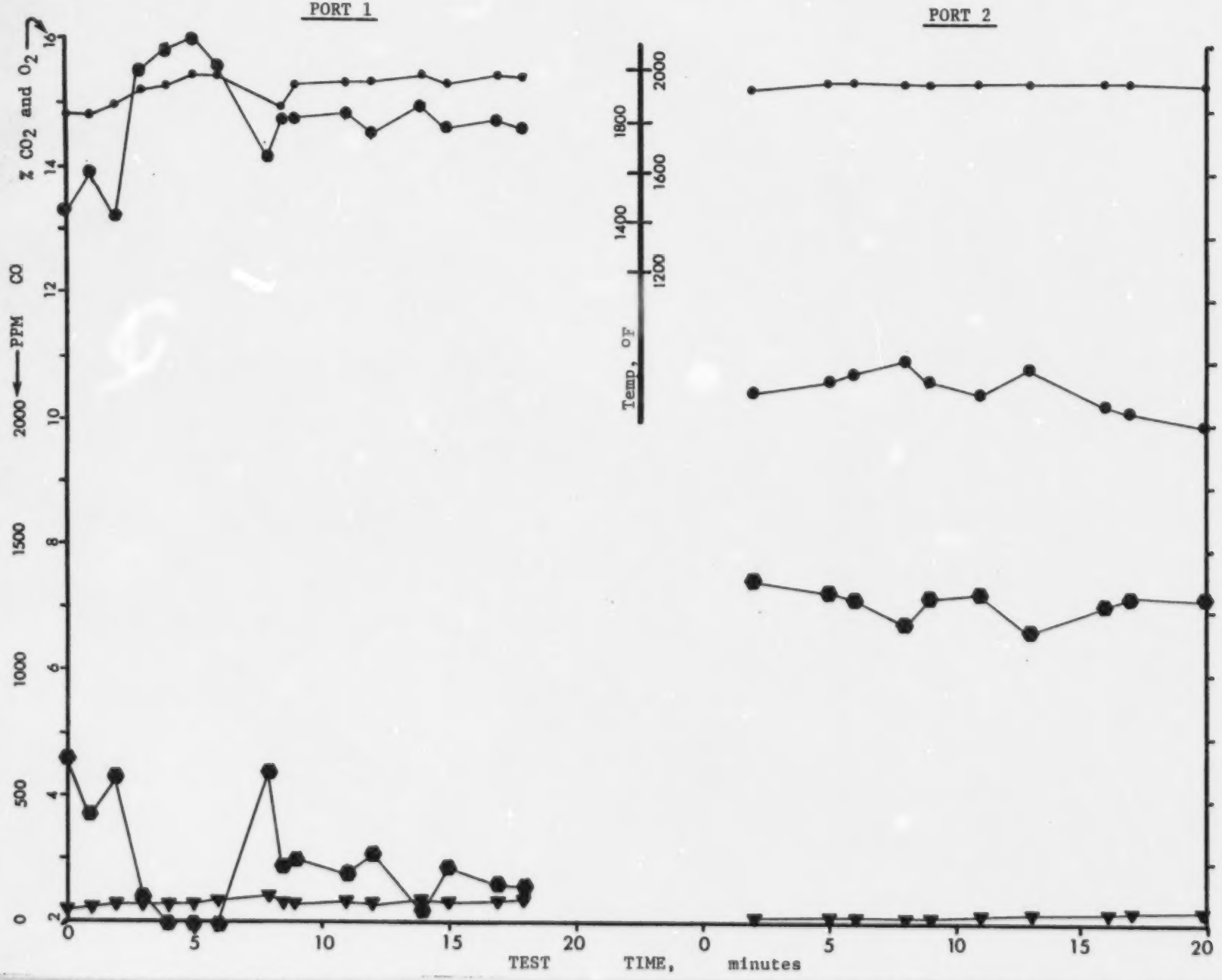
GRAPH 3. COMBUSTION ANALYSES DURING TEST 3.



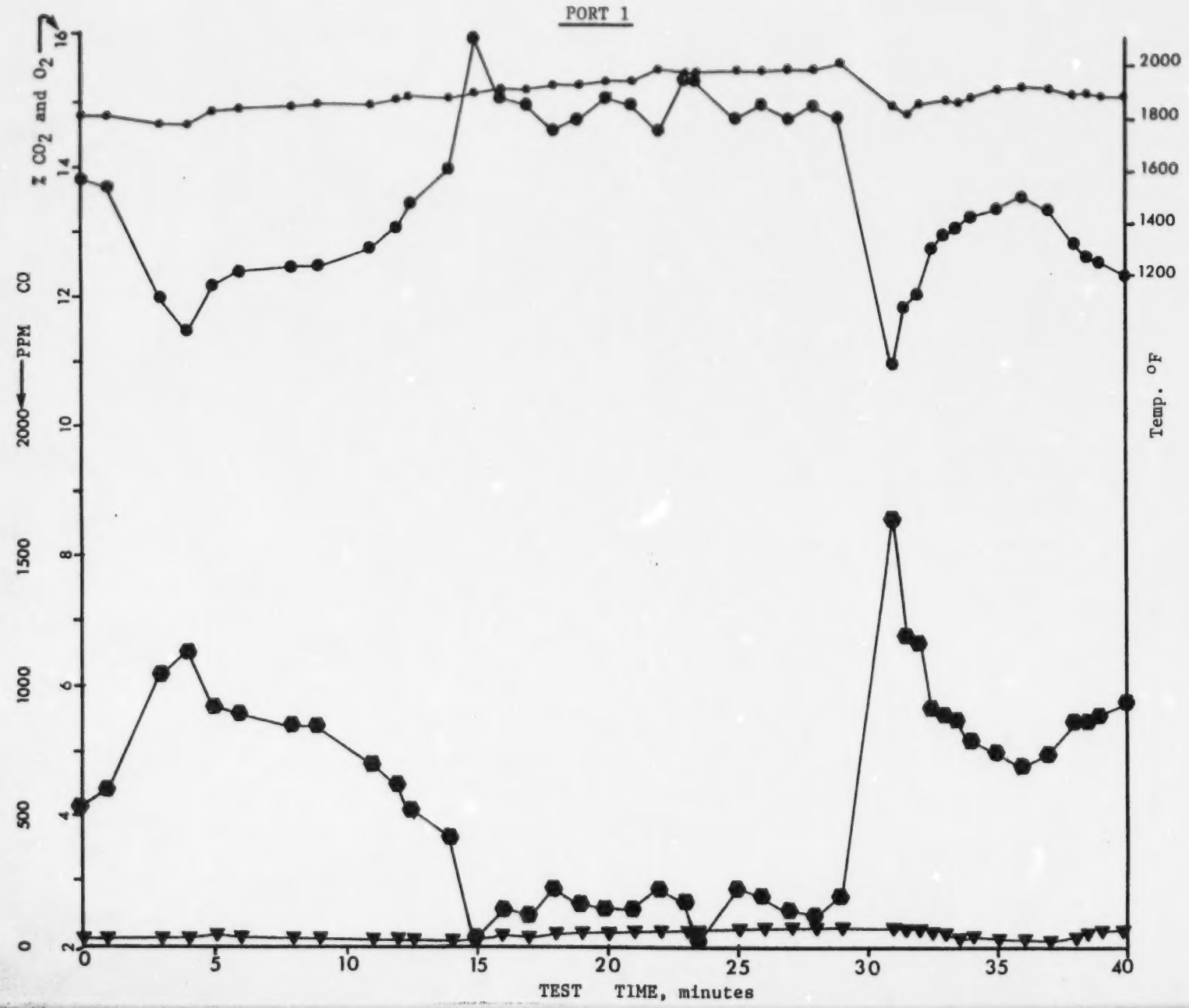
GRAPH 4. COMBUSTION ANALYSES DURING TEST 4.



GRAPH 5. COMBUSTION ANALYSES DURING TEST 5.



GRAPH 6. COMBUSTION ANALYSES DURING TEST 6



DISCUSSION

The concentration of emitted particulate varied considerably during the six tests. To understand what actually occurred one must consider that while the charge loaded into the primary chamber remained relatively uniform the operating characteristics of the incinerator were modified considerably from test to test in an effort to maximize unit efficiency while producing low particulate emissions.

All relevant parameters were combined to produce a coherant model (see graphs 1 to 6) for combustion analysis of individual tests, which are summarized as follows:

Test 1: High O_2 and CO combined with low CO_2 and temperature indicated that the natural gas flow rate to the burners was too low and the combustion air fan was supplying too much fresh air. The particulate emission concentration was approximately three times the limit.

Test 2: An increase in natural gas volume to the burners produced good combustion i.e. CO_2 and temperature were high while O_2 was suitably low. However a particulate emission concentration five times that of the limit indicated probable entrainment of particulate that would have settled out if the gas velocity had been lower.

Unfortunately the gas analyzer failed part way through the test due to particulate and water plugging the sensor chambers.

Test 3: Analysis of data from the first port indicates good combustion. However by the time that the second port was sampled the after burner temperature exceeded the high limit temperature and the gas burners were automatically shut off by the operation cycle timer. This was indicated by a sharp drop in temperature and a dramatic rise in CO levels, i.e. the results of incomplete combustion. The particulate emission concentration for this test was approximately two times the limit.

Test 4: Frequent adjustments to the natural gas and combustion air input rates produced high CO_2 and low O_2 and CO levels during sampling of the first port. However as the temperature was dangerously near the high temperature cut out point the natural gas input was decreased prior to sampling in port 2, resulting in slightly lower CO_2 and higher O_2 levels. A disturbance from within the primary chamber, possibly a sealed tin can exploded, may have contributed to a particulate emission concentration one and a half times the limit.

Test 5: In a similar pattern to Test 4 very good combustion was achieved during sampling of the first port by numerous natural gas input adjustments. During the sampling period of the second port a more stable but less efficient combustion was achieved. The particulate emission concentration was still over two times the acceptable limit.

Test 6: Average CO_2 level was the highest in this test for the series. Frequent adjustments were still necessary to stop the high temperature cut out from activating, producing a somewhat erratic combustion, especially near the start and finish of the test. This was the only test in which an acceptable particulate emission concentration was achieved.

A synoptic evaluation of the incinerator performance resulted in the following consideration that could increase combustion efficiency while minimizing the particulate released to the atmosphere:

i) The natural gas combustion air inputs need to be balanced (for each other) and custom tailored for the planned operational use of each incinerator. This would necessitate the use of a flue gas analyzer and stack thermocouple during the post installation inspection/check-out.

ii) The single position natural gas burners should be replaced with two position type burners with a high setting to achieve the desired combustion temperature and a low setting to maintain that temperature when the incinerator was operating near the high temperature cut out point. This would avoid abrupt and dramatic changes in the combustion process that disrupt the incinerator possibly causing entrainment of particulate (during

re-ignition) and incomplete oxidation of pathological materials (during the shutdown phase).

iii) The incinerator should be loaded according to specific recommendations i.e. a) wastes should be kept away from the primary burner exhaust, b) sealed gas cylinders should never be included in the waste, c) empty boxes should be broken down and placed on the floor of the primary chamber and d) the primary chamber should never be overloaded.

iv) Ash and non combustible residue should be removed from the primary chamber prior to each use.

CONCLUSION

Tests 1 to 5 indicate a particulate emission concentration varying from 0.32 g/dscm to 1.25 g/dscm at 12% CO_2. All five tests were in noncompliance with Manitoba Regulation 334/74, Section 3(1) limit of 0.23 g/dscm of flue gas corrected to 12% CO_2.

Test 6 indicates a particulate emission concentration of 0.14 g/dscm at 12% CO_2. In the latest state of adjustment the incinerator was in compliance with Manitoba Regulation 334/74, Section 3(1).

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3. Standard Reference Methods For Source Testing: Measurement Of Emission Of Particulates From Stationary Sources. Ottawa, Ont: Environment Canada, Environmental Protection Service, 1974 (Report EPS 1-AP-74-1).

APPENDIX A: EQUIPMENT CALIBRATION DATA

S-TYPE PITOT TUBE CALIBRATION

PROBE SIZE (ft) 5 CALIBRATION # 86-24

PROBE LINER Water Cooled DATE April 10, 1986

PROBE MANUFACTURER _____

TIP SIZE (inches) .500

STACK THERMOCOUPLE ☒ PRESENT

☐ ABSENT

HP 97 INPUT/OUTPUT

Temp	22.4	°C
Bar. Press	29.06	In. Hg
Scale Factor	0.1	

0.46	Δ p (std)	
14.531098		
0.72	Δ p (s-pitot)	
0.797307		
14.534143		

1.32	Δ p (std)	
24.615376		
2.12	Δp(s-pitot)	
0.787104		
24.620534		

0.10	Δ p (std)	
Tunnel Velocity 6.775159	ft/sec	
0.16	Δ p (s-pitot)	
Cp, at this 0.788593	velocity	
Tunnel Velocity 6.776579	(using Cp)	

0.62	Δ p (std)	
16.870010		
1.00	Δ p (s-pitot)	
0.785432		
16.873546		

1.85	Δ p (std)	
29.141061		
2.94	Δp(s-pitot)	
0.791271		
29.147169		

0.20	Δ p (std)	
9.581522		
0.31	Δ p (s-pitot)	
0.801211		
9.583530		

0.80	Δ p (std)	
19.163044		
1.25	Δ p (s-pitot)	
0.798000		
19.167060		

0.790583	Cp (ave)	
0.007881	Std. Dev.	
8	Deg. of Freedom	

0.32	Δ p (std)	
12.119773		
0.53	Δ p (s-pitot)	
0.775086		
12.122313		

1.12	Δ p (std)	
22.674019		
1.78	Δ p (s-pitot)	
0.791247		
22.678771		

2.306	t .05
0.784526	Low Cp
0.790583	Mean Cp
0.796641	High Cp

rev. 82-01

DRY GAS METER & ORIFICE METER CALIBRATION SHEET

Lab No 13386 ½

Dry Gas Meter S/N Rockwell 711030

Calibrated re Large Wet Test Meter

Atmospheric Pressure 29.30 in. Hg or 744.4 mm. Hg

Calibrated by Jim Pachopovich & Kevin Reese

Ambient Temperature 22.3°C

Date 14 July 84

Manometer Orifice ΔH (in. H_2O)	W.T.M. Volume V_w ($Ft.^3$)	Dry Gas Meter Reading Initial ($Ft.^3$)	Dry Gas Meter Reading Final ($Ft.^3$)	D.G.M. Volume Vd ($Ft.^3$)	Temperature W.T.M. Tw (°F.)	Temperature W.T.M. Tw (°C.)	Temperature D.G.M. Ti (°F.)	Temperature D.G.M. To (°F.)	Time t (Min.:Sec.)	Time t (Min.)	W.T.M. Manometer Δ m (in. H_2O)	Partial Pressure Ps (mm. Hg)	W.T.M.:D.G.M. Ratio γ (—)	$\sqrt{\quad}$ (—)	Flowrate Q C.F.M. Qm ($Ft.^3$/min.)
0.560	5.0	921.370	921.408	5.038	69.5	20.3	64	81	12:08.33	12.1472	0.24	17.864	1.0106	0.5972	0.4164
0.560	5.0	927.415	932.454	5.066	69.6	20.3	115	82	12:11.81	12.1918	0.34	17.814	1.0155	0.5978	0.4173
0.560	5.0	933.504	938.588	5.104	69.6	20.3	116	84	12:14.55	12.2425	0.36	17.864	1.0106	0.5989	0.4173
1.05	5.0	941.162	946.300	5.133	69.6	20.3	112	85	8.53.02	8.8837	0.48	17.864	0.9997	0.8203	0.5716
1.05	5.0	947.831	952.981	5.150	69.7	20.4	112	86	8.53.77	8.8962	0.45	17.974	0.9986	0.8210	0.5743
1.05	5.0	954.012	959.171	5.159	69.7	20.4	112	86	8.54.54	8.9090	0.38	17.974	0.9964	0.8210	0.5736
1.52	6.0	962.268	968.475	6.207	69.8	20.4	114	87	8.50.40	8.8400	0.56	17.974	0.9947	0.9882	0.6916
1.54	6.0	969.515	975.720	6.205	69.9	20.5	114	87	8.50.67	8.8445	0.41	18.0855	0.9950	0.9946	0.6912
1.53	7.0	977.763	984.007	7.244	69.9	20.5	114	87	10:18.40	10.3067	0.43	18.085	0.9943	0.9914	0.6920
2.08	7.0	987.115	994.378	7.263	69.0	20.6	116	87	8.59.99	8.9998	0.70	18.197	0.9911	1.1552	0.7792
2.08	7.0	995.414	2.690	7.276	69.0	20.6	117	87	9.00.44	9.0001	0.67	18.197	0.9903	1.1552	0.7792
2.08	7.0	3.724	11.005	7.281	69.0	20.6	117	88	9.00.74	9.0001	0.47	18.197	0.9910	1.1562	0.7810

Linear Regression: Intercept (b) 0.0215

Slope (K) 0.6580

Coefficient of Determination (r^2) 0.9994

$\bar{\gamma}$ = 0.9957 ± 0.0083

$\Delta H@$ = 2.1226

Comments:

#245 Rev. 9/23/83 JP/cm

DRY GAS METER & ORIFICE METER CALIBRATION SHEET

Lab No. 13386 2/2

Dry Gas Meter S/N: Bendix 711030

Atmospheric Pressure: 29.30 in hg = 744.4 mm hg

Ambient Temperature: 22.3°C

Calibrated re: Large Wet Test Meter

Calibrated by: Jim Prokopovich & Kevin Reese

Date: 14 July 86

Manometer Orifice ΔH (in. H_2O)	W.T.M. Volume Vw ($Ft.^3$)	Dry Gas Meter Reading Initial ($Ft.^3$)	Dry Gas Meter Reading Final ($Ft.^3$)	D.G.M. Volume Vd ($Ft.^3$)	Temperature W.T.M. Tw (°F.)	Temperature W.T.M. Tw (°C.)	Temperature D.G.M. Ti (°F.)	Temperature D.G.M. To (°F.)	Time t (Min.:Sec.)	Time t (Min.)	W.T.M. Manometer Δm (in. H_2O)	Partial Pressure Ps (mm. Hg)	W.T.M./D.G.M. Ratio γ (—)	$\sqrt{\quad}$ (—)	Flowrate Q S.T.P. Qm ($Ft.^3$/min.)
2.53	8.0	39033	47404	8.321	69.1	20.6	117	88	9 19 44	9.3240	0.58	18.197	0.9894	1.2744	0.8563
2.53	8.0	48.445	51.773	8.325	69.1	20.6	117	88	9 19 42	9.3237	0.58	18.197	0.9889	1.2744	0.8563
2.53	8.0	57.515	61.134	8.319	69.2	20.7	117	88	9 19.77	9.3295	0.69	18.310	0.9890	1.2744	0.8592
3.07	8.0	69.255	77.569	8.314	69.3	20.7	118	89	8 30 19	8.5032	0.58	18.310	0.9901	1.4042	0.9432
3.08	8.0	79.145	87.965	8.317	69.4	20.8	118	89	8 30 53	8.5088	0.82	18.422	0.9888	1.4065	0.9417
3.06	8.0	89.005	97.324	8.319	69.5	20.8	119	89	8 30 49	8.5082	0.69	18.422	0.9896	1.4019	0.9419

Linear Regression: Intercept (b) _____

Slope (K) _____

Coefficient of Determination (r^2) _____

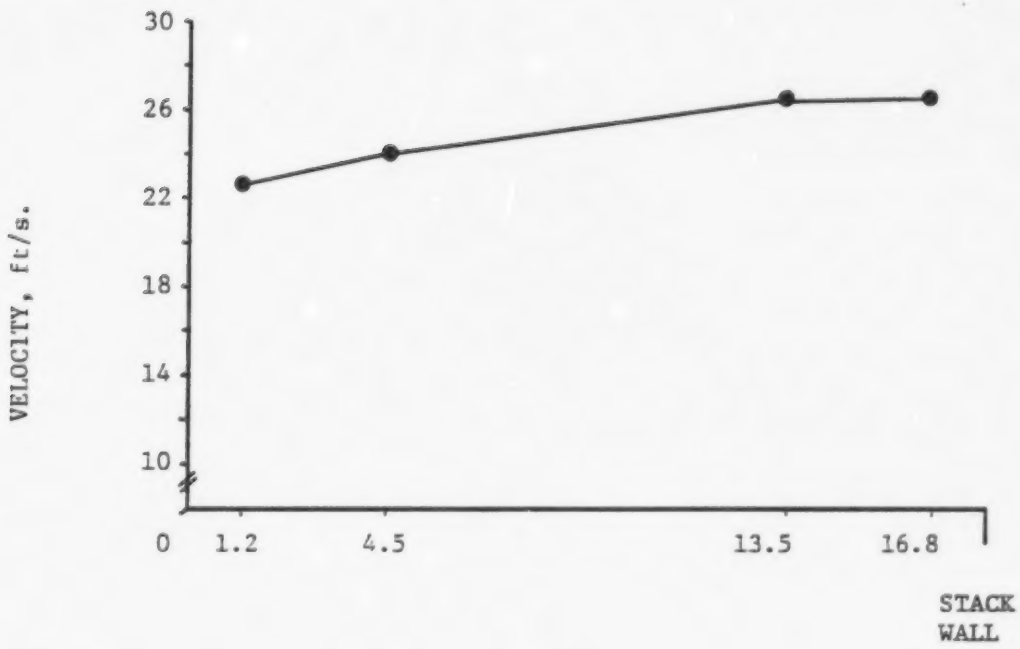
$\bar{\gamma}$ = _____

ΔH@ = _____

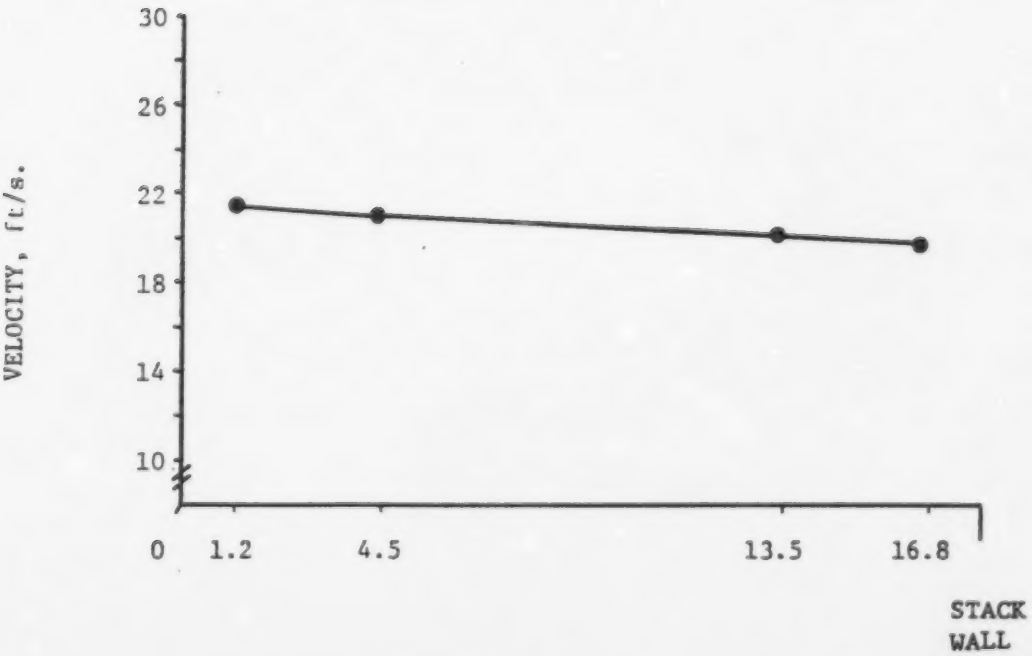
Comments: _____

APPENDIX B: VELOCITY PROFILES

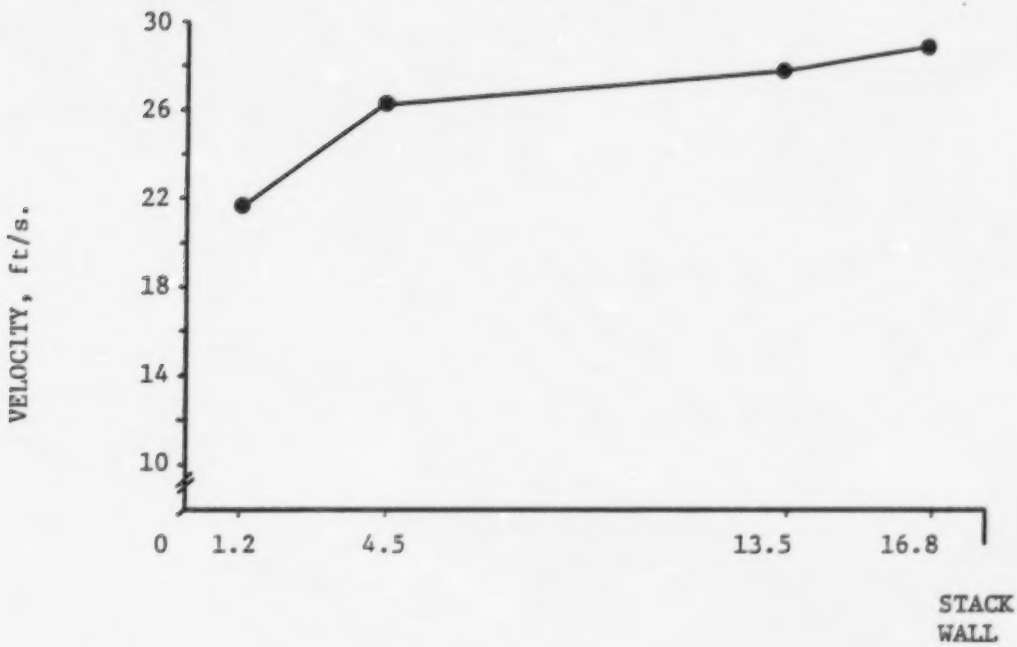
GRAPH 7 . VELOCITY PROFILE OF TEST 1 . SOUTHWEST PORT



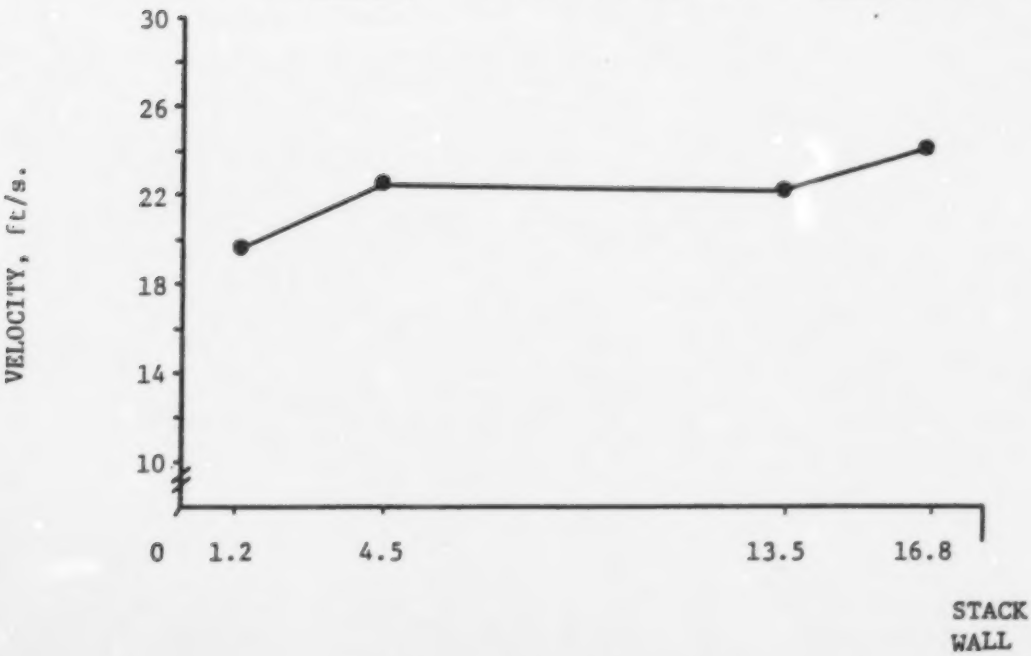
GRAPH 8 . VELOCITY PROFILE OF TEST 1 . NORTHWEST PORT



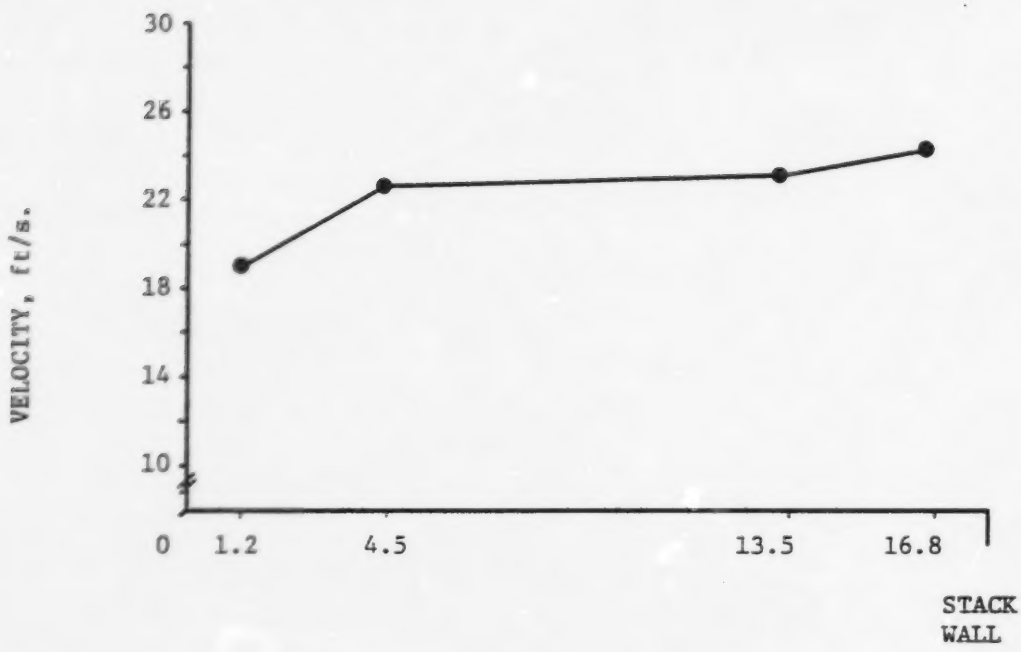
GRAPH 9 . VELOCITY PROFILE OF TEST 2 . SOUTHWEST PORT



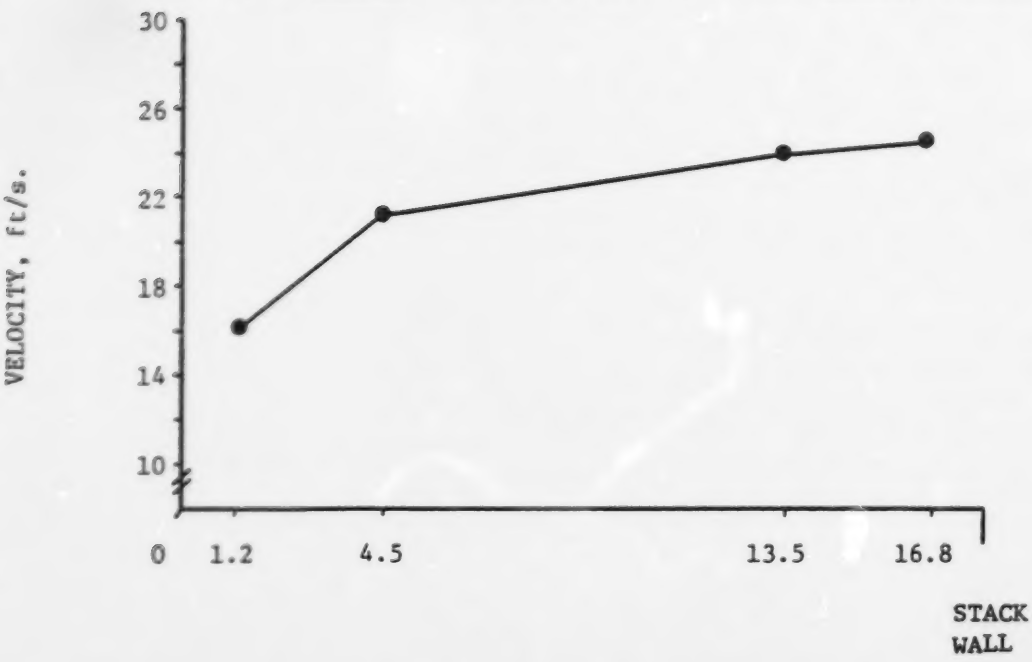
GRAPH 10 . VELOCITY PROFILE OF TEST 2 . NORTHWEST PORT



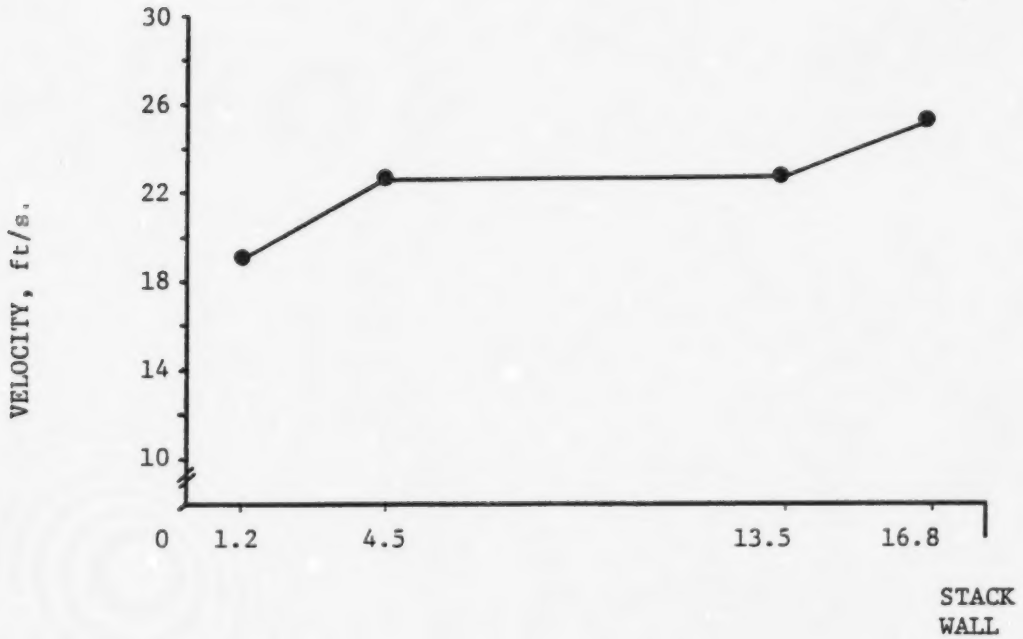
GRAPH 11 . VELOCITY PROFILE OF TEST 3 . SOUTHWEST PORT



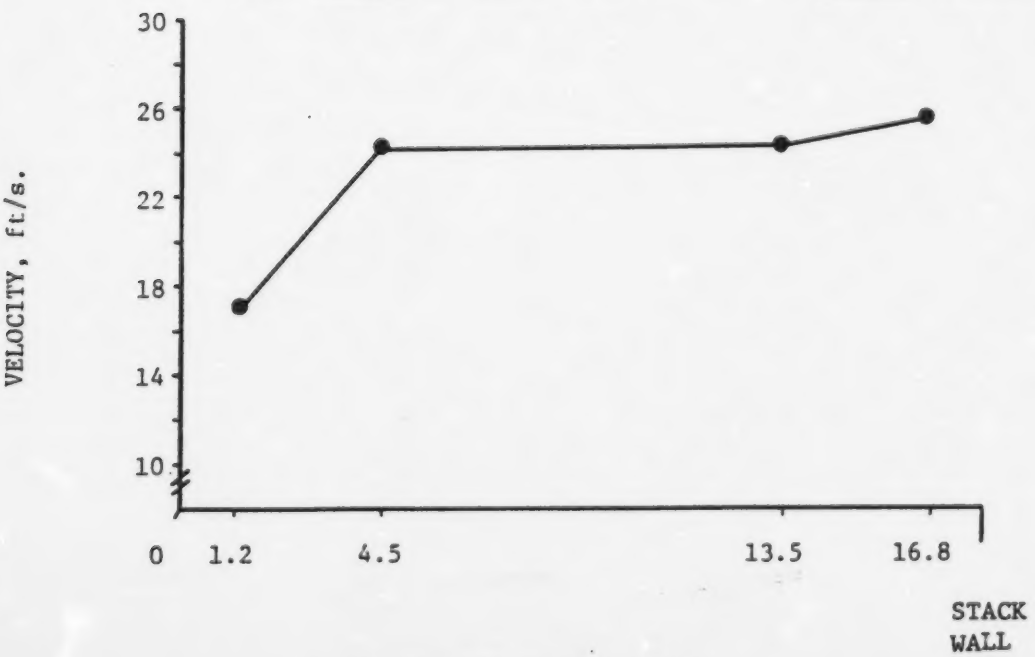
GRAPH 12 . VELOCITY PROFILE OF TEST 3 . NORTHWEST PORT



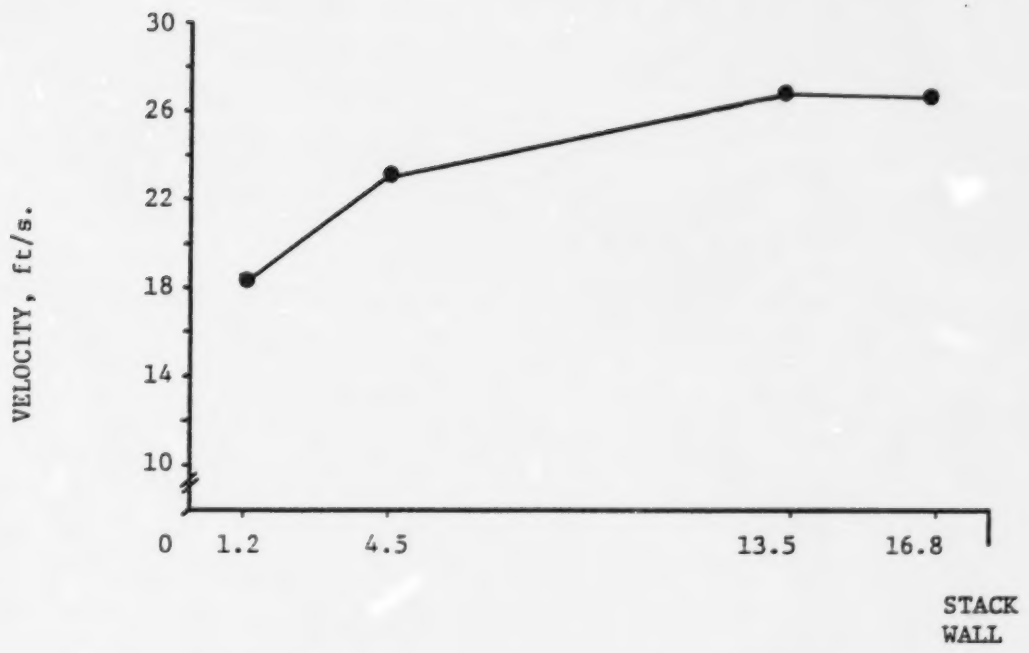
GRAPH 13 . VELOCITY PROFILE OF TEST 4 . SOUTHWEST PORT



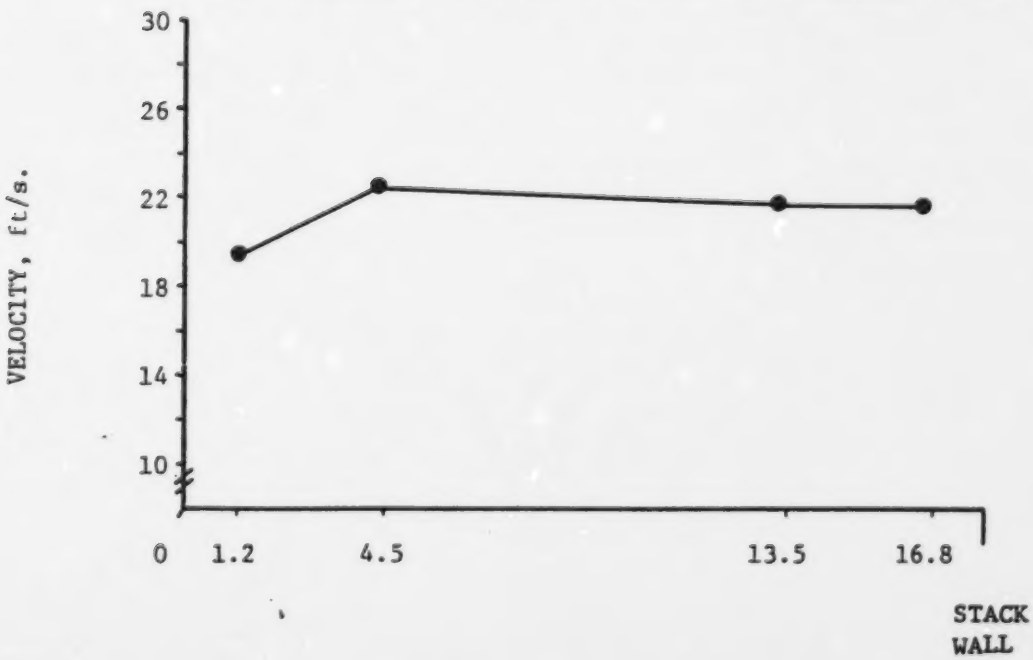
GRAPH 14 . VELOCITY PROFILE OF TEST 4 . NORTHWEST PORT



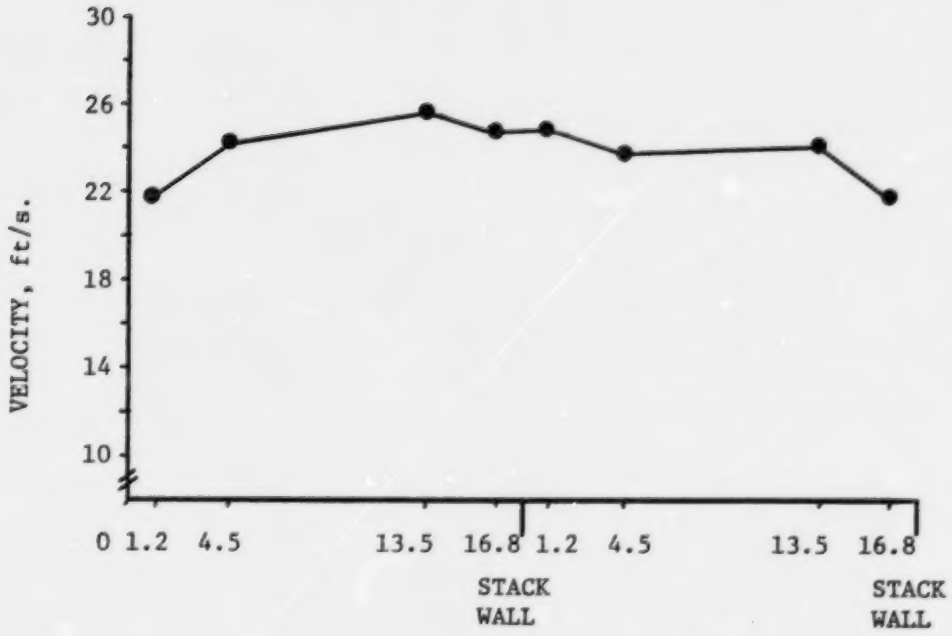
GRAPH 15. VELOCITY PROFILE OF TEST 5. SOUTHWEST PORT



GRAPH 16. VELOCITY PROFILE OF TEST 5. NORTHWEST PORT



GRAPH 17. VELOCITY PROFILE OF TEST 6. SOUTHWEST PORT.



APPENDIX C: FIELD DATA SHEETS

FIELD DATA SHEET

Plant MORDEN DISTRICT GENERAL HOSPITAL Location 30 STEPHEN STREET, MORDEN, MANITOBA

Stack Pathological Incinerator Test number 1 Date September 8, 1986

Ambient temperature (°F) 63 Barometric pressure (in. Hg) 29.22 Time 10:52 A.M. to 11:57 A.M.

Nozzle diameter (in.) 0.495 Probe length/type 5 ft./water cooled Stack static pressure (in. H_2O) -0.120

Probe temperature (°F) - Filter holder temperature (°F) ave. 265 Leak check 0.005 CFM @ 15" Hg Vacuum

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	1,416	2.445	0.050	0.824	88	80	51	3	106.9
2	5	1,396	2.629	0.057	0.949	94	79	48	4	106.7
3	10	1,350	3.099	0.075	1.274	99	79	48	4	107.6
4	15	1,170	3.474	0.085	1.640	103	79	48	5	107.5
2 - 1	20	1,399	2.361	0.045	0.746	97	84	51	3	106.7
2	25	1,294	2.457	0.046	0.807	102	84	51	3	106.3
3	30	1,281	2.246	0.038	0.678	103	85	53	3	106.3
4	35	1,281	2.182	0.037	0.639	105	85	56	3	104.7
Average or total	40	1,323	20.893	0.054	0.945	-	-	-	-	106.6

FIELD DATA SHEET

Plant MORDEN DISTRICT GENERAL HOSPITAL Location 30 STEPHEN STREET, MORDEN, MANITOBA

Stack Pathological Incinerator Test number 2 Date September 10, 1986

Ambient temperature (°F) 61 Barometric pressure (in. Hg) 28.97 Time 10:24 A.M. to 11:09 A.M.

Nozzle diameter (in.) 0.495 Probe length/type 5 ft/water cooled Stack static pressure (in. H_2O) -0.155

Probe temperature (°F) - Filter holder temperature (°F) ave. 298 Leak check 0.002 CFM @ 15 " Hg Vacuum

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	1,678	1.968	0.040	0.536	79	76	54	4	107.7
2	5	1,843	2.220	0.055	0.687	90	75	52	4	106.7
3	10	1,879	2.290	0.060	0.718	96	75	52	4	105.6
4	15	1,889	2.435	0.065	0.795	100	76	52	4	107.7
2 - 1	20	1,840	1.595	0.030	0.366	90	77	56	3	103.3
2	25	1,837	1.910	0.040	0.492	97	77	55	4	106.5
3	30	1,762	1.945	0.040	0.512	98	78	54	4	106.6
4	35	1,719	2.164	0.048	0.628	100	78	54	4	107.0
Average or total	40	1,806	16.527	0.047	0.592	-	-	-	-	106.4

FIELD DATA SHEET

Plant MORDEN DISTRICT GENERAL HOSPITAL Location 30 STEPHEN STREET, MORDEN, MANITOBA

Stack Pathological Incinerator Test number 3 Date September 11, 1986

Ambient temperature (°F) 70 Barometric pressure (in. Hg) 28.98 Time 10:54 A.M. to 11:42 A.M.

Nozzle diameter (in.) 0.495 Probe length/type 5 ft/water cooled Stack static pressure (in. H_2O) - 0.155

Probe temperature (°F) - Filter holder temperature (°F) ave. 249 Leak check 0.000 CFM @ 15" Hg Vacuum

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	1,842	1.601	0.029	0.358	82	79	56	1	105.4
2	5	1,863	1.823	0.040	0.488	91	77	54	2	101.8
3	10	1,873	1.911	0.042	0.509	94	77	52	2	104.1
4	15	1,941	1.955	0.045	0.535	97	77	53	3	104.4
2 - 1	20	1,860	1.161	0.020	0.241	90	79	57	1	91.7
2	25	1,916	1.649	0.034	0.407	97	79	56	2	100.6
3	30	1,918	1.923	0.043	0.517	100	79	57	3	103.8
4	35	1,924	1.950	0.045	0.535	100	80	57	3	102.8
Average or total	40	1,892	13.973	0.037	0.449	-	-	-	-	101.8

FIELD DATA SHEET

Plant MORDEN DISTRICT GENERAL HOSPITAL Location 30 STEPHEN STREET, MORDEN, MANITOBA

Stack Pathological Incinerator Test number 4 Date September 16, 1986

Ambient temperature (°F) 48 Barometric pressure (in. Hg) 29.51 Time 11:17 A.M to 12:05 P.M.

Nozzle diameter (in.) 0.495 Probe length/type 5 ft/water cooled Stack static pressure (in. H_2O) 0.155

Probe temperature (°F) - Filter holder temperature (°F) ave. 263 Leak check 0.015 CFM @ 15 " Hg Vacuum

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	1,865	1.562	0.029	0.358	86	81	54	2	103.8
2	5	1,954	1.777	0.040	0.474	98	81	57	3	101.7
3	10	1,900	1.893	0.041	0.496	102	82	59	3	105.4
4	15	1,949	2.065	0.049	0.586	106	83	62	4	105.8
2 - 1	20	1,962	1.313	0.022	0.260	95	85	64	3	101.4
2	25	1,935	1.972	0.045	0.537	104	85	67	3	105.0
3	30	1,893	2.030	0.046	0.561	108	85	71	3	105.4
4	35	1,920	2.134	0.051	0.619	110	85	71	4	105.8
Average or total	40	1,922	14.746	0.040	0.486	-	-	-	-	104.3

FIELD DATA SHEET

Plant MORDEN DISTRICT GENERAL HOSPITAL Location 30 STEPHEN STREET, MORDEN, MANITOBA

Stack Pathological Incinerator Test number 5 Date September 17, 1986

Ambient temperature (°F) 51 Barometric pressure (in. Hg) 29.05 Time 11:10 A.M. to 11:53 A.M.

Nozzle diameter (in.) 0.495 Probe length/type 5 ft/water cooled Stack static pressure (in. H_2O) - 0.155

Probe temperature (°F) - Filter holder temperature (°F) ave. 293 Leak check 0.001 CFM @ 15" Hg Vacuum

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	1,809	1.563	0.027	0.344	90	86	48	2	109.0
2	5	1,975	1.813	0.040	0.472	102	86	47	3	106.2
3	10	1,980	2,107	0.053	0.628	109	87	48	3	106.8
4	15	1,982	2.119	0.052	0.615	111	88	50	3	108.1
2 - 1	20	1,962	1.519	0.028	0.337	107	89	51	3	105.4
2	25	1,996	1.747	0.037	0.436	111	90	52	3	105.6
3	30	1,980	1.715	0.035	0.416	112	90	54	3	106.2
4	35	1,976	1.714	0.035	0.418	114	91	55	3	105.7
Average or total	40	1,958	14.297	0.038	0.458	-	-	-	-	106.6

FIELD DATA SHEET

Plant MORDEN DISTRICT GENERAL HOSPITAL Location 30 STEPHEN STREET, MORDEN, MANITOBA

Stack Pathological Incinerator Test number 6 Date September 22, 1986

Ambient temperature (°F) 71 Barometric pressure (in. Hg) 29.05 Time 11:09 A.M to 11:49 A.M.

Nozzle diameter (in.) 0.495 Probe length/type 5 ft/water cooled Stack static pressure (in. H_2O) -0.155

Probe temperature (°F) - Filter holder temperature (°F) ave. 255 Leak check 0.000 CFM @ 15" Hg Vacuum

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	1,754	1.922	0.036	0.493	92	87	53	3	109.6
2	5	1,875	2.092	0.046	0.586	96	84	52	3	108.1
3	10	1,875	2.215	0.051	0.652	97	84	53	3	108.6
4	15	1,918	2.136	0.047	0.596	100	84	55	3	109.8
4	20	1,967	2.114	0.047	0.583	103	84	55	3	109.7
3	25	2,008	1.965	0.042	0.512	105	85	56	3	108.6
2	30	1,884	2.138	0.046	0.585	106	86	56	3	109.7
1	35	1,899	1.896	0.037	0.472	106	86	56	3	108.6
Average or total	40	1,894	16.478	0.044	0.560	-	-	-	-	109.1

APPENDIX D: ANALYTICAL REPORTS

Manitoba

Environment and Workplace Safety and Health

Environmental Management

Building 2
139 Tuxedo Avenue
Winnipeg, Manitoba, CANADA
R3N 0H6

LABORATORY CHEMICAL ANALYSES REPORT: METAL ANALYSES OF PROBE AND FILTER SAMPLES FROM MORDEN DISTRICT GENERAL HOSPITAL

November 21, 1986

		Fe	Cr	Ni	Mo
TEST 1	PROBE	68,000	4,487	11,500	83.3
(Sept. 8/86)	FILTER	6,600	1,346	875	300
TEST 2	PROBE	95,000	19,550	4,500	667
(Sept. 10/86)	FILTER	14,400	3,526	2,375	1,604
TEST 3	PROBE	28,000	5,192	4,875	225
(Sept. 11/86)	FILTER	13,200	2,244	1,875	2,083
TEST 4	PROBE	71,739	7,391	9,861	283
(Sept. 16/86)	FILTER	20,870	4,239	2,500	1,292
TEST 5	PROBE	156,500	34,783	21,944	667
(Sept. 17/86)	FILTER	21,740	4,891	2,611	1,375
TEST 6	PROBE	11,000	1,667	3,188	8.3
(Sept. 22/86)	FILTER	2,000	139	100	41.6

Notes: 1) Date analyzed - November 18, 1986
2) Units µg

W.M. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: K. REEVE
LOCATION: MODERN GENERAL HOSPITAL — TEST # I
REPORT TO: K. REEVE — E.P.C.
ER-1

SAMPLE – ID
From: Y 86 Sequent 17817
To: Y 86 Sequent 17819

L – Less than
G – Greater than

Date Sampled: Y 86 M 09 D 08
Date Received: Y 86 M 09 D 09

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analysed
17817	1) BATTLE # 1	TSP		0.1284	g	86,09,15
17818	2) BATTLE # 2	TSP		0.0112	g	86,09,15
17819	3) FILTER # 501	TSP		0.0555	g	86,09,15

Chemist Signature _____ Date 86/09/23

WM. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: KEVIN REEVE
LOCATION: MORDEN GEN. HOSP. STACK EMISSIONS
REPORT TO: KEVIN REEVE AEC
BLDG 2 FOC TEST 2

SAMPLE – ID From: Y 86 Sequent 18390 To: Y 86 Sequent 18302

L – Less than
G – Greater than

Date Sampled: Y 86 M 09 D 20
Date Received: Y 86 M 09 D 22

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analysed
18300	BOTTLE #1 PROBE WASHINGS + GLASSWARE BEFORE FILTER	TSP		0.,6339	g	86.09.18
18301	BOTTLE #2 IMANGER 1&2 CONTENTS	TSP		0..0066	g	86.09.18
18302	FILTER #502	TSP		0..0661	g	86.09.18

Date 86/09/23

Chemist Signature

W.M. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: KEVIN REEVE
LOCATION: MORDEN GEN. HOSP. STACK EMISSIONS
REPORT TO: KEVIN REEVE ARC
BLDG 2 FOC TEST 3

From SAMPLE – ID: Y 86 Sequent 18303
To: Y 86 Sequent 18305

L – Less than
G – Greater than

Date Sampled: Y 86 M 09 D 11
Date Received: Y 86 M 09 D 12

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analysed
18303	BOTTLE #1	TSP		0.2139	g	86.09.18
	PROBE WASHINGS					
	+ GLASSWARE					
	BEFORE FILTER					
18304	BOTTLE # 2	TSP		0.0140	g	86.09.18
	IMPINGER #1 + #2					
	CONTENT					
18305	FILTER #503	TSP		0.0637	g	86.09.18

Chemist Signature _____ Date 86/09/23

W.M. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: K. REEVE
LOCATION: MORDEN GENERAL HOSPITAL
REPORT TO: K. REEVE — F.O.C.
TEST 4 ER-1

SAMPLE – ID
From: Y 86 Sequent 18786
To: Y 86 Sequent 18788

L – Less than
G – Greater than

Date Sampled: Y 86 M 09 D 16
Date Received: Y 86 M 09 D 18

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analysed
18786	1) BOTTLE #1	CR-T		73.91	ug/filter	86.10.17
		NI-T		98.61		
		FE-T		717.39		
		MO-T		2.83		
		TSP		0.183	g	86.09.23
18787	2) BOTTLE #2	TSP		0.056	g	86.09.23
18788	FILTER 505	CR-T		42.39	ug/filter	86.10.17
		NI-T		25.00		
		FE-T		208.70		
		MO-T		12.92		
		TSP		0.1069	g	86.09.23

OCT 20 1986

Date 86/10/20

Operator Signature

W.M. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: K. REEVE
LOCATION: MORDEN GENERAL HOSPITAL
REPORT TO: K. REEVE — E. & C.
TESTS ER-1

From SAMPLE – ID: Y 86 Sequent 18789
To: Y 86 Sequent 18791

L – Less than
G – Greater than

Date Sampled: Y 86 M 09 D 17
Date Received: Y 86 M 09 D 18

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analyzed
18789	1) BOTTLE #1	CR-T		34783	ug/filty	86 10 17
		NI-T		21944		
		FE-T		156500		
		MO-T		667		
		TSP		0.5021	g	86 04 23
18790	2) BOTTLE #2	TSP		0.00468	g	86 09 25
18791	FILTER 506	CR-T		48911	ug/filty	86 10 17
		NI-T		26111		
		FE-T		217402		
		MO-T		13751		
		TSP		0.01777	g	86 09 25

OCT 20 1986

Date 86 10 23

Chemist Signature

W.M. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: KEVIN REELE
LOCATION: MORDEN GEN. HOSPITAL
REPORT TO: K. REELE
BLDG 2 FOC TEST 6

SAMPLE – ID From: Y 86 Sequent 18995 To: Y 86 Sequent 18997

L – Less than
G – Greater than

Date Sampled: Y 86 M 09 D 22
Date Received: Y 86 M 09 D 23

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analysed
18995	BOTTLE #1	TSP		0.0559	g	86.09.29
18996	BOTTLE #2	TSP		0.0149	g	86.09.29
18997	FILTER # 507	TSP		0.0218	g	86.09.29

Date 86 10 24

Chemist Signature